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Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams EPA 841-B-06-002

Chapter 2 Condition of the Nation's Streams

May 2006

Chapter 2 – Condition of the Nation's Streams

Background

The CWA explicitly aims "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." This report examines these three aspects of water quality through a small set of commonly used and widely accepted indicators. Although this report does not include all aspects of biological integrity, or review all possible chemical, physical, or biological stressors known to affect water quality, it does present the results of important indicators for an entire class of water resources—wadeable, perennial streams.

This chapter describes the results of the WSA and is organized as follows:

- Indicators of Biological Condition provides a description of the indicators or attributes of biological condition that were measured by the WSA survey and the results of the data analysis.
- Aquatic Indicators of Stress presents findings on the stressors evaluated for the study.
- Ranking of Stressors presents an analysis of the relative importance of the stressors in affecting biological condition.
- Results for each indicator are shown for the nation's streams and for the three climatic and landform regions (Eastern Highlands, Plains and Lowlands, and West). Chapter 3 of this report presents indicator results for each of the nine WSA ecoregions.

Indicators of Biological Condition

Ecologists evaluate the biological condition of water resources, including wadeable streams, by analyzing key characteristics of the communities of organisms that live in these waterbodies. These characteristics include the composition and relative abundance of key groups of animals (e.g., fish and invertebrates) and plants (e.g., periphyton, or algae that attach themselves to stream bottoms, rocks, and woody debris) found in streams. The WSA focused on just one assemblage, benthic macroinvertebrates (e.g., aquatic insects, crustaceans, worms and mollusks). Some WSA participants also researched other assemblages.

Why focus on macroinvertebrates? Macroinvertebrates are key organisms that reflect the quality of their environment and respond to human disturbance in fairly predictable ways. As all fly-fisherman know, the insects emerging from streams and rivers are good indicators of the quality of waters and an important food source for both game and non-game fish. Given the wide geographic distribution of macroinvertebrates, as well as their abundance and link to fish and other aquatic vertebrates, these organisms serve as excellent indicators of the quality of flowing waters and the human stressors that affect these systems.

WSA researchers collected samples of these organisms and sent them to laboratories for analysis, yielding a data set that provided the types and number of taxa (i.e., classifications or groupings of organisms) found at each site. To interpret this data set, the WSA used two measures of biological condition: the Macroinvertebrate Index of Biotic Condition and the Observed/Expected (O/E) Ratio of Taxa Loss.

Highlight: Using Multiple Biological Assemblages to Determine Biological Condition

EPA's guidance on developing biological assessment and criteria programs recommends the use of multiple biological assemblages to determine biological condition. The term "multiple biological assemblages" simply refers to the three main categories of life found in our waters: plants, including algae; macroinvertebrates; and vertebrates such as fish. The purpose of examining multiple biological assemblages rather than only one is to generate a broader perspective of the condition of the aquatic resource of interest.

Each assemblage plays a different role in the way rivers and streams function. Algae and macroinvertebrates occur throughout all types and sizes of streams, while very small streams may be naturally devoid of fish. Algae are the base of the food chain and capture light and nutrients to create life. They are sensitive to changes in shading, turbidity, and increases or decreases in nutrients. Macroinvertebrates feed both on algae and on other organic material that enter the aquatic system from the surrounding watershed. Macroinvertebrates also form the base of the food chain for many, though not all, aquatic vertebrates. Fish are an important food source for people and wildlife, and are themselves generally dependent on macroinvertebrates for food. Each of these groups of aquatic organisms is sensitive in its own way to different human-induced disturbances.

The WSA collaboration began as a partnership among 12 western states, EPA Regions 8, 9, and 10, and EPA's Western Ecology Division (EMAP West) before it was expanded to include the rest of the United States. This original EMAP West program addressed fish, macroinvertebrates, and algae. Future WSA reports will also address multiple assemblages.

To learn more about EMAP West and its use of multiple biological assemblages, visit www.epa.gov/emap/west/index.html.

Macroinvertebrate Index of Biotic Condition

The Macroinvertebrate Index is similar in concept to the economic Consumer Confidence Index (or the Leading Index of Economic Indicators) in that the total index score is the sum of scores for a variety of individual measures, also called indicators or metrics. To determine the Leading Index, economists look at a number of metrics, including manufacturers' new orders for consumer goods, building permits, money supply, and other aspects of the economy that reflect economic growth. To determine the Macroinvertebrate Index, ecologists look at such metrics as taxonomic richness, habit and trophic composition, sensitivity to human disturbance, and other aspects of the biota that reflect "naturalness." Originally developed as an Index of Biotic Integrity for fish in Midwestern streams, the Index of Biotic Condition has been modified and applied to other regions, taxonomic groups, and ecosystems.

The metrics used to develop the Macroinvertebrate Index for the WSA covered six different characteristics of macroinvertebrate assemblages that are commonly used to evaluate biological condition:

- **Taxonomic richness:** This characteristic represents the number of distinct taxa, or groups of organisms, identified within a sample. Many different kinds of distinct taxa, particularly those that belong to the pollution-sensitive insect groups, indicate a variety of physical habitats and food sources and an environment exposed to generally lower levels of stress.

- **Taxonomic composition:** Ecologists calculate composition metrics by identifying the different taxa groups, determining which taxa in the sample are ecologically important, and comparing the relative abundances of organisms in those taxa to the whole sample. Healthy stream systems have organisms from across many different taxa groups, whereas unhealthy stream systems are often dominated by high abundance of organisms in a small number of taxa that are tolerant of pollution.
- **Taxonomic diversity:** Diversity metrics look at all the taxa groups and the distribution of organisms among those groups. Healthy streams should have a high level of diversity throughout the assemblage.
- **Feeding groups:** A taxon's feeding strategy is captured in the feeding metrics. Many macroinvertebrates have specialized strategies to capture and process food from their aquatic environment. As a stream degrades from its natural condition, the distribution of animals among the feeding groups will change. For example, as a stream loses its canopy (a source of leaves and shading), the aquatic community will shift to one of predominantly algal-feeding animals that are tolerant of warm water.
- **Habits:** Just like other organisms, benthic macroinvertebrates are characterized by certain habits, including how they move and where they live. These habits are captured in the habit metrics. For example, some taxa burrow under the streambed sediment, whereas others cling to rocks and debris within the stream channel. A stream that naturally includes a diversity of habitat types will support animals with diverse habits. If, for example, a stream becomes laden with silt, the macroinvertebrates that cling, crawl, and swim will be replaced by those that burrow.
- **Pollution tolerance:** Each macroinvertebrate taxa can tolerate a specific range of stream contamination, which is referred to as their pollution tolerance. Once this level is exceeded, the taxa are no longer present in that area of the stream. Highly sensitive taxa, or those with a low pollution tolerance, are found only in streams with good water quality.

What are taxa?

Taxa (plural of taxon) are groupings of living organisms, such as phylum, order, family, genus, or species. Biologists use taxonomy to scientifically describe and organize organisms into taxa to better identify and understand them.

The specific metrics chosen for each of these categories varied among the nine ecoregions used in the analysis (see Appendix A). Each metric was scored and then combined to create an overall Macroinvertebrate Index for each region, with values ranging from 0 to 100. For the WSA, analysts calculated a Macroinvertebrate Index score for each site, factored in the stream length represented by the site, and then generated an estimate of the length of stream in a region, and nationally, with a given Macroinvertebrate Index score.

Findings for the Macroinvertebrate Index

As illustrated in Figure 2-1, 42% of the nation's stream length is in poor condition, and 25% is in fair condition compared to the least-disturbed reference condition in each of the nine WSA ecoregions. The 28% of stream miles rated good have conditions most similar to the reference distribution derived from the best available sites in each ecoregion. The 5% of unassessed stream length results from the fact that 1st order streams in New England were not sampled for the WSA.

Macroinvertebrate Index of Biotic Condition

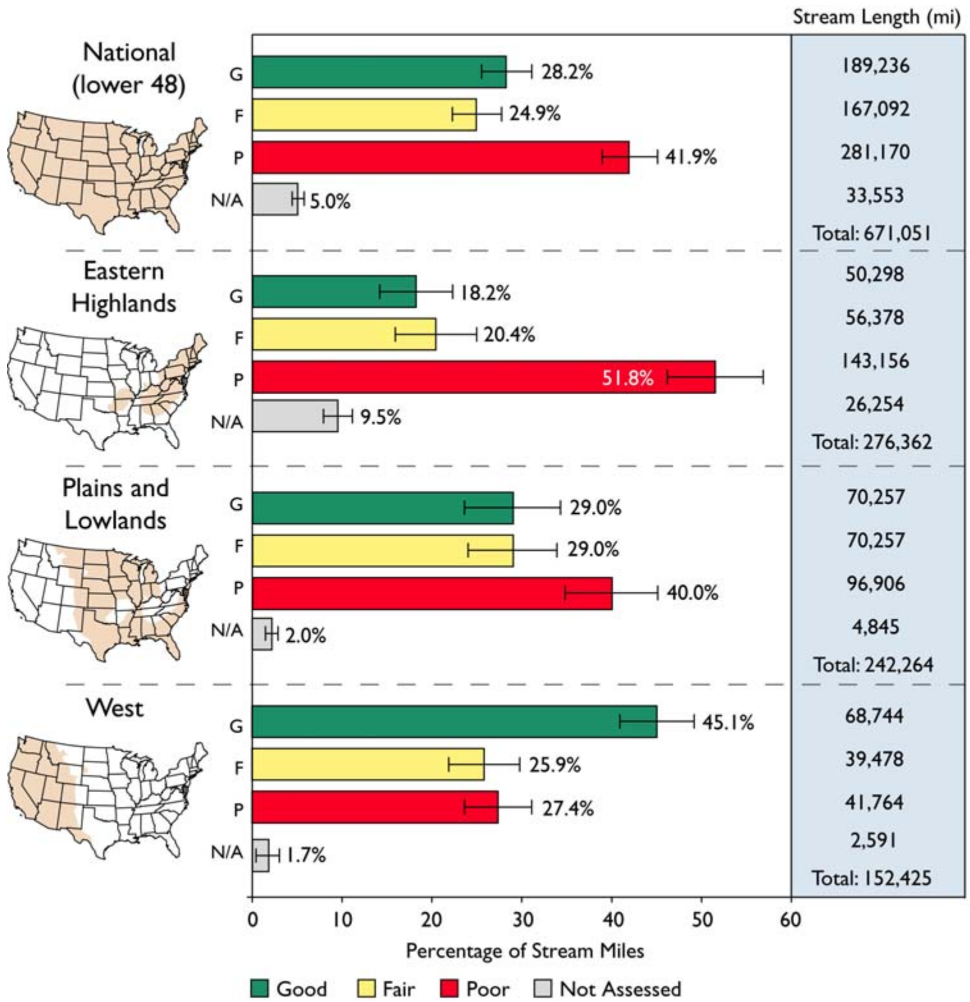

Figure 2-1. Biological condition of streams based on Macroinvertebrate Index of Biotic Condition.

The benthic Macroinvertebrate Index combines metrics of benthic community structure and function into a single index for each region. The thresholds for defining good, fair, and poor condition were developed for each of the nine WSA ecological regions based on the condition at the best available regional reference sites. Stream resources in good condition are most similar to least-disturbed reference condition. The intermediate category, fair, has Macroinvertebrate Index scores worse than 75% of reference. The poor streams have Macroinvertebrate Index scores worse than 95% of reference.

The Eastern Highlands region has the largest proportion of streams (52%) in poor condition for macroinvertebrate integrity, followed by the Plains and Lowlands (40%) and the West (27%). Chapter 3 provides the results for each of the 9 WSA ecoregions.

What are confidence intervals?

Confidence intervals (i.e., the small lines at the end of the bars in the report's charts) are provided to convey some sense of the certainty or confidence that can be placed in the information presented in this document. For example, for the national macroinvertebrate index of biotic condition, the WSA finds that 28.2% of the stream length is in good condition and our confidence is +/- 2.8%, which generally means that we are 95% sure that the real value is between 25.4% and 31%. The confidence interval depends primarily on the number of sites that were sampled. In general terms, as more streams are sampled, the confidence interval becomes narrower, meaning there is more confidence in the findings. When fewer streams are visited, the confidence intervals become broader, meaning there is less certainty in the findings. This pattern can be seen in Figure 2-1, in which the confidence interval for the national results (the largest sample size) is narrowest; in the climatic regions and ecoregions, on the other hand, smaller numbers of streams were sampled and the confidence intervals are generally broader. Ultimately the breadth of the confidence interval will be a trade off between the need for increased certainty to support decisions and the money and resources dedicated to monitoring.

Macroinvertebrate Observed/Expected (O/E) Ratio of Taxa Loss

The O/E measure looks at a specific aspect of biological health: taxa that have been lost at a site. The taxa expected (E) at individual sites are predicted from a model developed from data collected at reference sites. The model thus allows a precise matching of sampled taxa with those that should occur under specific, natural environmental conditions. By comparing the list of taxa observed (O) at a site with those expected to occur, we can quantify the proportion of expected taxa that have been lost as the ratio of O/E. Originally developed for streams in the United Kingdom, models are modified for the specific natural conditions in each area for which it is used. The O/E is currently used by several countries and numerous states in the United States.

O/E values range from 0 (none of the expected taxa are present) to slightly greater than 1 (more taxa are present than expected). O/E values are interpreted as the percentage of the expected taxa present. Each tenth of a point less than 1 represents a 10% loss of taxa at the site; thus, an O/E score of 0.9 indicates that 90% of the expected taxa are present and 10% are missing. O/E values must be interpreted in context of the quality of reference sites used to build the predictive models because the quality of reference sites available in a region sets the bar for what is expected. Regions with lower-quality reference sites will have a lower bar. Although an O/E value of 0.8 means the same thing regardless of a region, i.e., 20% of taxa have been lost relative to reference conditions in each region, the true amount of taxa loss will be underestimated if reference sites are of low quality.

The WSA developed three O/E models to predict the extent of taxa loss across streams of the United States: one for the Eastern Highlands, one for the Plains and Lowlands, and one for the West. Analysts used the O/E scores observed at each site to generate estimates of the lengths of stream in the U.S. estimated to fall into four categories of taxa loss.

Although in many cases the results of the O/E Taxa Loss analysis are similar to the results of the Macroinvertebrate Index, such agreement will not always occur. The O/E examines a specific aspect of biological condition (biodiversity loss), whereas the Macroinvertebrate Index combines multiple characteristics. For the WSA, the two indicators provided similar results in those WSA ecoregions that had a lower disturbance signal among their reference sites.

Findings for O/E Taxa Loss

Figure 2-2 displays the national and regional taxa loss summary for the nation's stream resource. These data are presented in four categories: (1) less than 10% taxa loss, (2) 10 – 20% taxa loss, (3) 20 – 50% taxa loss, (4) and more than 50% taxa loss. Across the country, 42% of the stream miles have lost less than 10% of the expected taxa, which means they have retained more than 90% of their taxa; 13% have lost 10 – 20%; 26% have lost 20 – 50% of the expected taxa; and 13% of the stream miles have lost more than 50% of the expected taxa. Within the three major regions, the Eastern Highlands has experienced the greatest loss of expected taxa, with 17% of the stream length having experienced a loss of 50% or more. An additional 29% has lost 20 – 50% of the expected taxa; 13% have lost 10 – 20%; and only 28% of streams have lost fewer than 10% of the expected taxa.

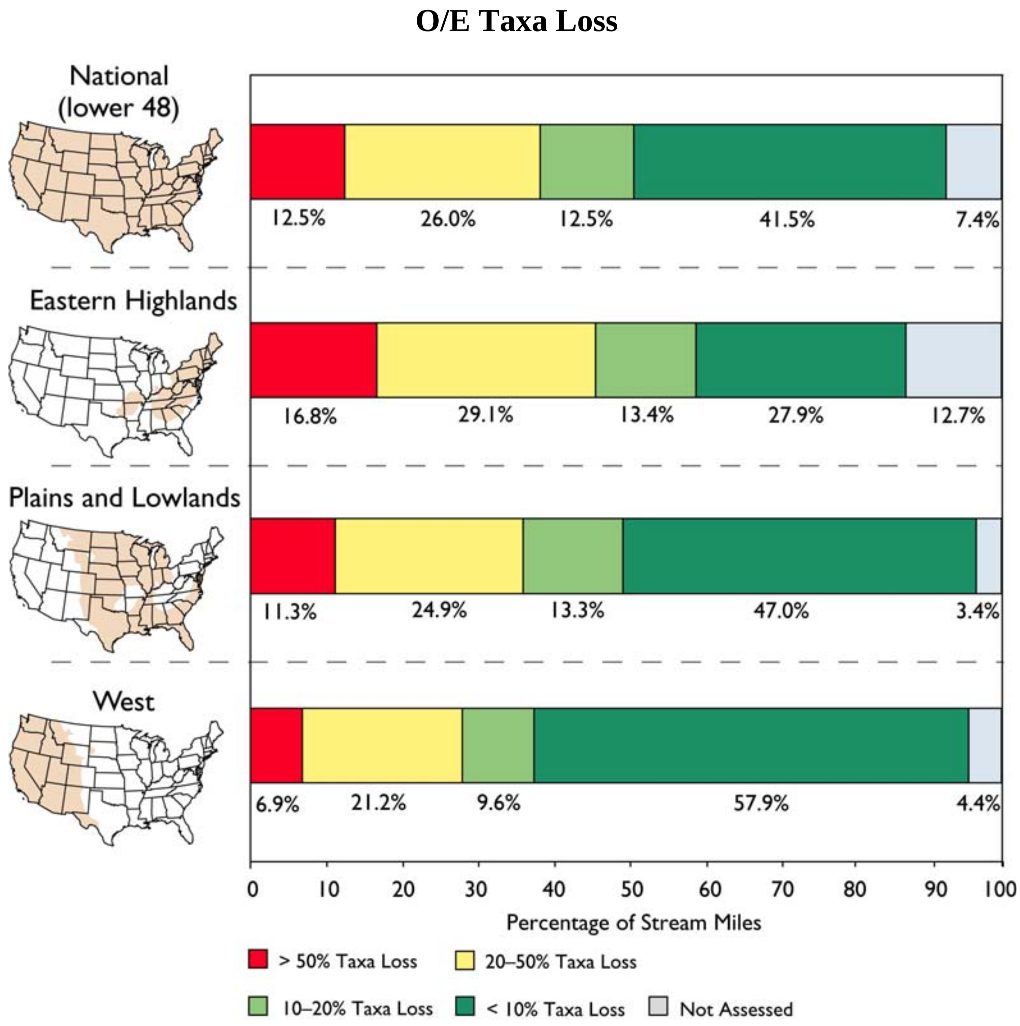

Figure 2-2. Macroinvertebrate taxa loss as measured by the Observed/Expected (O/E) Ratio.

The O/E predictive model displays the loss of taxa from a site compared to reference for that region. Scores 0.1 lower than reference represent a 10% loss in taxa.

Aquatic Indicators of Stress

As people use the landscape, their actions can produce effects that are stressful to aquatic ecosystems. These aquatic stresses can be chemical, physical, or in some cases, biological. In this WSA, we have selected a short list of stressors from each of these categories. This list is not intended to be all-inclusive, and in fact, some important stressors are not included because there is no current way to assess them at the site scale (e.g., water withdrawals for irrigation). Future assessments of U.S. stream and river condition will include a more comprehensive list of stressors from each of these categories.

WSA stressor indicators are based on direct measures of stress in the stream or adjacent riparian areas, not on land use or land cover alterations such as row crops, mining, or grazing. Although any form of human land use can be a source of one or more stressors to streams, the WSA chose to focus only on the stressors, rather than on their sources.

The summary results for indicators of chemical and physical habitat are shown in Figures 2-3 through 2-10. Results for each of the nine WSA ecoregions are presented in Chapter 3 of this report.

Chemical Stressors

Four chemical stressors were assessed in the WSA: total phosphorus, total nitrogen, salinity, and acidification. These stressors were selected because of national or regional concerns about the extent to which each might be impacting the quality of stream biota. The thresholds for interpreting data were developed from a set of least-disturbed reference sites for each of the nine WSA ecoregions, as described in Chapter 1.5 (*Setting Expectations*). The results for each ecoregion were tallied to report on conditions for the three major regions and the entire nation. See Appendix A for more details on the development of regional thresholds for all indicators.

Highlight: Nutrients and Eutrophication in Streams

Eutrophication is a condition characterized by excessive plant growth that results from too many nutrients in a waterbody. Eutrophication is a natural process, but human activities can accelerate it by increasing the rate at which nutrients and organic substances enter waters from their surrounding watersheds. Agricultural runoff, urban runoff, leaking septic systems, sewage discharges, eroded streambanks, and similar sources can increase the flow of nutrients and organic substances into streams, and subsequently, into downstream lakes and estuaries. These substances can overstimulate the growth of algae and aquatic plants, creating conditions that interfere with recreation and the health and diversity of insects, fish, and other aquatic organisms.

Nutrient enrichment due to human activities has long been recognized as one of the leading problems facing our nation's lakes, reservoirs, and estuaries, and has also been more recently recognized as a contributing factor to stream degradation. In broadest terms, nutrient over-enrichment of streams is a problem because of 1) negative impacts on aquatic life (the focus of the WSA); 2) adverse health effects on humans and domestic animals; 3) aesthetic and recreational use impairment; and 4) excessive nutrient input into downstream waterbodies, such as lakes.

Excess nutrients in streams can lead to excessive growth of phytoplankton (free-floating algae) in slow-moving rivers, periphyton (algae attached to the substrate) in shallow streams, and macrophytes (aquatic plants large enough to be visible to the naked eye) in all waters. Unsightly filamentous algae can impair our aesthetic enjoyment of streams. In more extreme situations, excessive growth of aquatic plants can slow water flow in flat streams and canals, interfere with swimming, snag fishing lures, and clog the screens on water intakes of water treatment plants and industries.

Nutrient enrichment has also been demonstrated to affect stream animal communities (see references for examples of published studies). For example, declines in invertebrate community structure have been correlated directly with increases in phosphorus concentration. High concentrations of nitrogen in the form of ammonia (NH_3) are known to be toxic to aquatic animals. Excessive levels of algae have also been shown to be damaging to invertebrates. Finally, fish and invertebrates will grow poorly and can even die if either oxygen is depleted or pH increases are severe; both of these conditions are symptomatic of eutrophication.

As a system becomes more enriched by nutrients, different species of algae may spread and species composition can shift. However, unless such species shifts cause clearly demonstrable water-quality symptoms—such as fish kills, toxic algae or very long streamers of filamentous algae—the general public is unlikely to be aware of a potential ecological concern.

Total Phosphorus Concentration

Phosphorus is usually considered the most likely nutrient limiting algal growth in U.S. freshwater waterbodies. Because of the naturally low levels of phosphorus in stream systems, even small increases in phosphorus levels can impact a stream's water quality. Some areas of the country have naturally higher levels of phosphorus, such as streams originating from groundwater in volcanic areas like eastern Oregon and Idaho. This natural variability is reflected in the regional thresholds for high, medium, and low, which are based on the least-disturbed reference sites for each of the 9 WSA ecoregions.

Phosphorus influx leads to increased algal growth, which reduces dissolved oxygen levels and water clarity within the stream. (See the Highlight on nutrients and eutrophication for more information about the impacts of excess phosphorus and nitrogen.) Phosphorus is a common component of fertilizers, and high concentrations in streams may be associated with poor agricultural practices, urban runoff, or point-source discharges (e.g., effluents from sewage treatment plants).

Findings for Total Phosphorus

Approximately 31% of stream length nationwide has high levels of phosphorus, 16% has medium levels, and 49% has low levels (Figure 2-3). Of the three climatic and landform regions, the Eastern Highlands has the greatest proportion of stream miles with high levels of phosphorus (43%), followed by the Plains and Lowlands (25%) and the West (19%).

Total Nitrogen Concentration

Nitrogen, another nutrient, is particularly important as a contributor to coastal and estuarine algal blooms. Nitrogen is the primary limiting nutrient in many regions of the United States, particularly in granitic or basaltic geology found in parts of the Northeast and the Pacific Northwest. Increased nitrogen inputs to a stream can stimulate growth of excess algae, such as periphyton, which results in low dissolved oxygen levels, a depletion of sunlight available to the streambed, and degraded habitat conditions for benthic macroinvertebrates and other aquatic life (see Highlight on nutrients and eutrophication). Common sources of nitrogen include fertilizers, wastewater, animal wastes, and atmospheric deposition.

Total Phosphorus

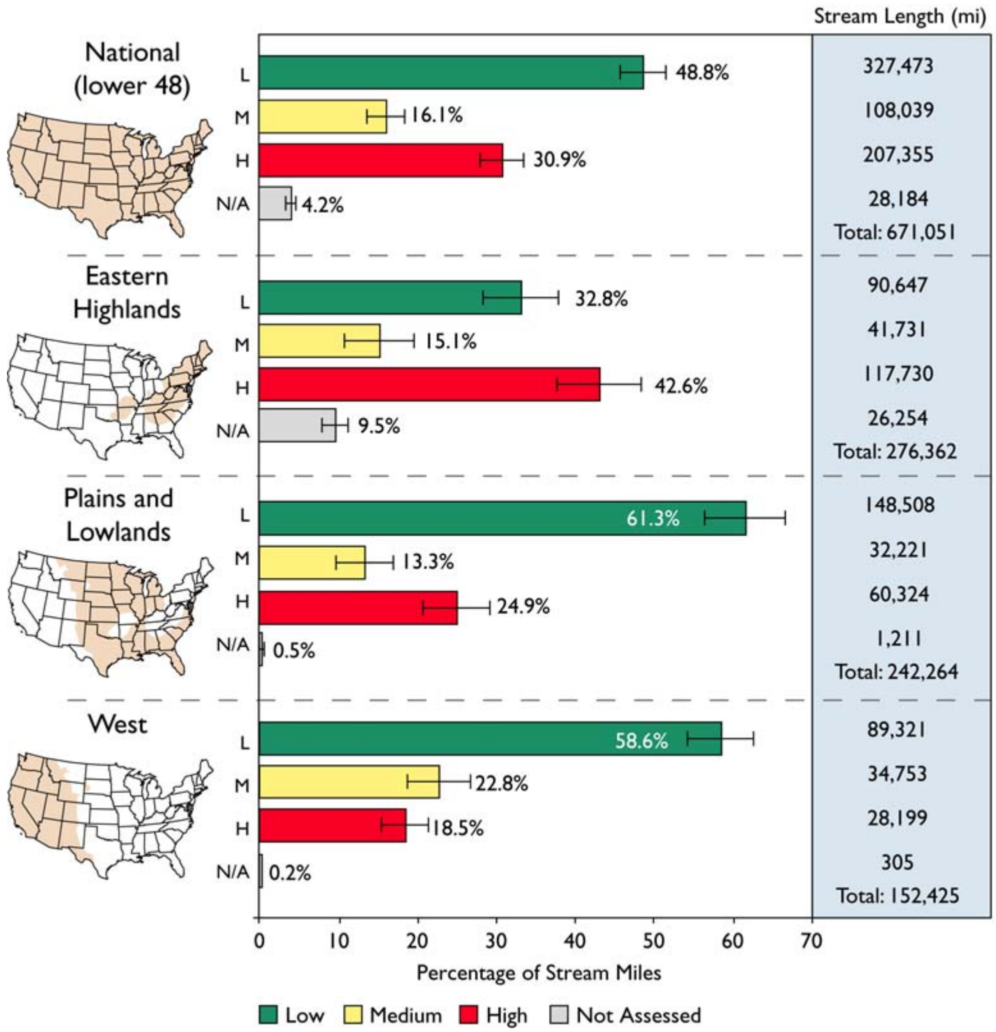

Figure 2-3. Total phosphorus concentrations in U.S. streams.

This is the percent of stream miles with low, medium, and high levels of phosphorus based on regionally relevant thresholds derived from the best quality regional reference sites. Low concentrations are most similar to reference condition. Medium concentrations are higher than the 75th percentile of reference condition. High concentrations are higher than the 95th percentile.

Findings for Total Nitrogen

A significant portion of stream miles (32%) have high levels of nitrogen compared to least-disturbed reference conditions. Another 21% have medium levels, and 43% of stream miles have relatively low levels (Figure 2-4). As with phosphorus, the Eastern Highlands region has the highest proportion of stream length with high levels of nitrogen (42%), followed by the Plains and Lowlands (27%) and the West (21%).

Total Nitrogen

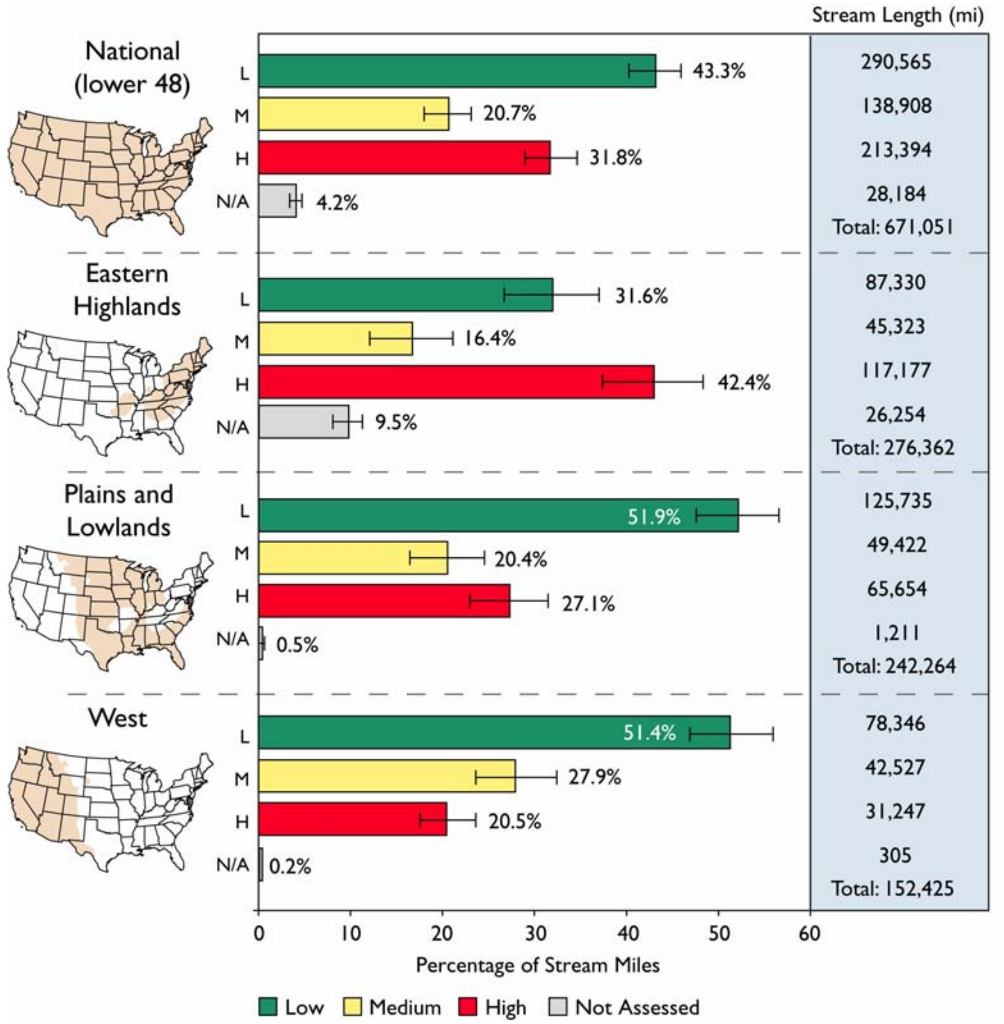

Figure 2-4. Total nitrogen concentrations in U.S. streams.

This is the percent of stream miles with low, medium, and high levels of nitrogen based on regionally relevant thresholds derived from the best-quality regional reference sites. Low concentrations were most similar to reference condition. Medium concentrations were higher than the 75th percentile of reference condition. High concentrations were defined as higher than the 95th percentile.

Salinity

Excessive salinity occurs in areas with high evaporative losses of water and can be exacerbated by repeated use of water for irrigation or by water withdrawals. Both electrical conductivity and total dissolved solids (TDS) can be used as measures of salinity; however, conductivity was used for the WSA.

Findings for Salinity

Roughly 3% of stream length nationwide has high levels of salinity, 10% has medium levels, and 83% has low levels compared to the levels found in least-disturbed reference sites for the 9 WSA ecoregions (Figure 2-5). The Plains and Lowlands region has the highest proportion of stream length with high levels of salinity (5%), followed by the West (3%). In the Eastern Highlands, high levels of salinity are found in about 1% of stream length.

Salinity

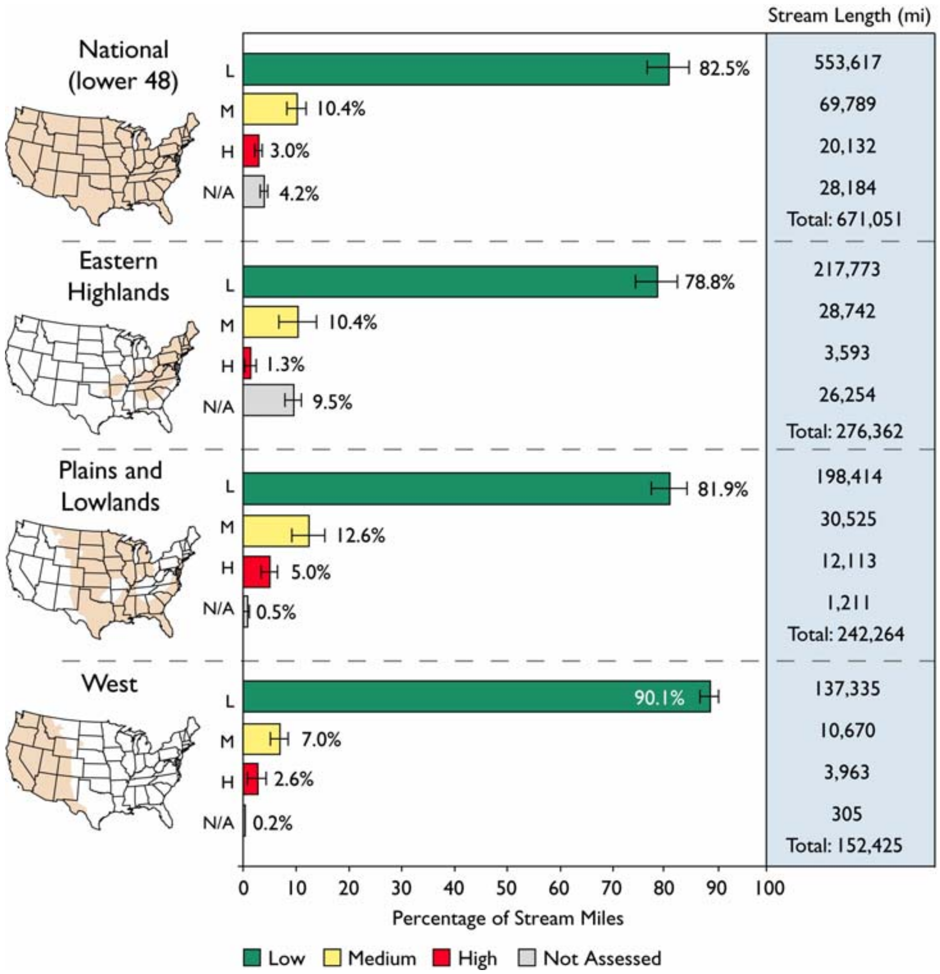

Figure 2-5. Salinity conditions in U.S. streams.

This indicator is based on electrical conductivity measured in water samples. Thresholds are based on conditions at regional reference sites.

Acidification

Streams and rivers can become acidic through the effects of acid deposition (e.g., acid rain) or mine drainage, particularly from coal mining. Previous studies have shown that these issues, while of concern, tend to be focused in a few geographic regions of the country. Streams and rivers can also be acidic because of such natural sources as high dissolved organic compounds. For the WSA assessment, we have chosen to identify the extent of systems that are not acidic, naturally acidic (i.e., similar to reference), and acidic because of anthropogenic disturbance. This last category includes streams that are acidic because of deposition, whether chronic or episodic, and streams that are acidic because of mine drainage.

Acid rain forms when smokestack and automobile emissions (particularly sulfur dioxide and nitrogen oxides) combine with moisture in the air, forming dilute solutions of sulfuric and nitric acid. Acid deposition can also occur in dry form, such as the particles that make up soot. When wet and dry deposition fall on sensitive watersheds, they can have deleterious effects on soils, vegetation, and streams and rivers.

In assessing acid rain's effects on flowing waters, the WSA relied on a measure of the water's ability to buffer inputs of acids, called acid neutralizing capacity or ANC. When ANC values fall below zero, the water is considered acidic and can be either directly or indirectly toxic to biota (e.g., by mobilizing toxic metals such as aluminum). When ANC is between 0 and 25 milliequilivents, the water is considered sensitive to episodic acidification during rainfall events.

Acid mine drainage forms when water moves through mines and mine tailings, combining with sulfur-bearing minerals to form strong solutions of sulfuric acid and mobilizing many toxic metals. As in the case of acid rain, the acidity of waters in mining areas can be assessed by using their ANC values. Mine drainage also produces extremely high concentrations of sulfate—much higher than those found in acid rain. Although sulfate is not directly toxic to biota, it serves as an indicator of mining's influence on streams and rivers. When ANC and sulfate are low, acidity can be attributed to acid rain. When ANC is low and sulfate is high, acidity can be attributed to acid mine drainage. Mine drainage itself, even if not acidic, can cause harm to aquatic life. The WSA does not include an assessment of the extent of mine drainage that is not acidic.

Findings for Acidification

Figure 2-6 shows that nationally, about 2% of the stream length is impacted by acidification from anthropogenic sources. This includes acid deposition (0.7%), acid mine drainage (0.4%), and stream miles likely to be episodically acidic during high runoff events (1%). Although these numbers appear relatively small, they reflect a significant impact in certain parts of the United States (particularly in the Eastern Highlands region).

Acidification

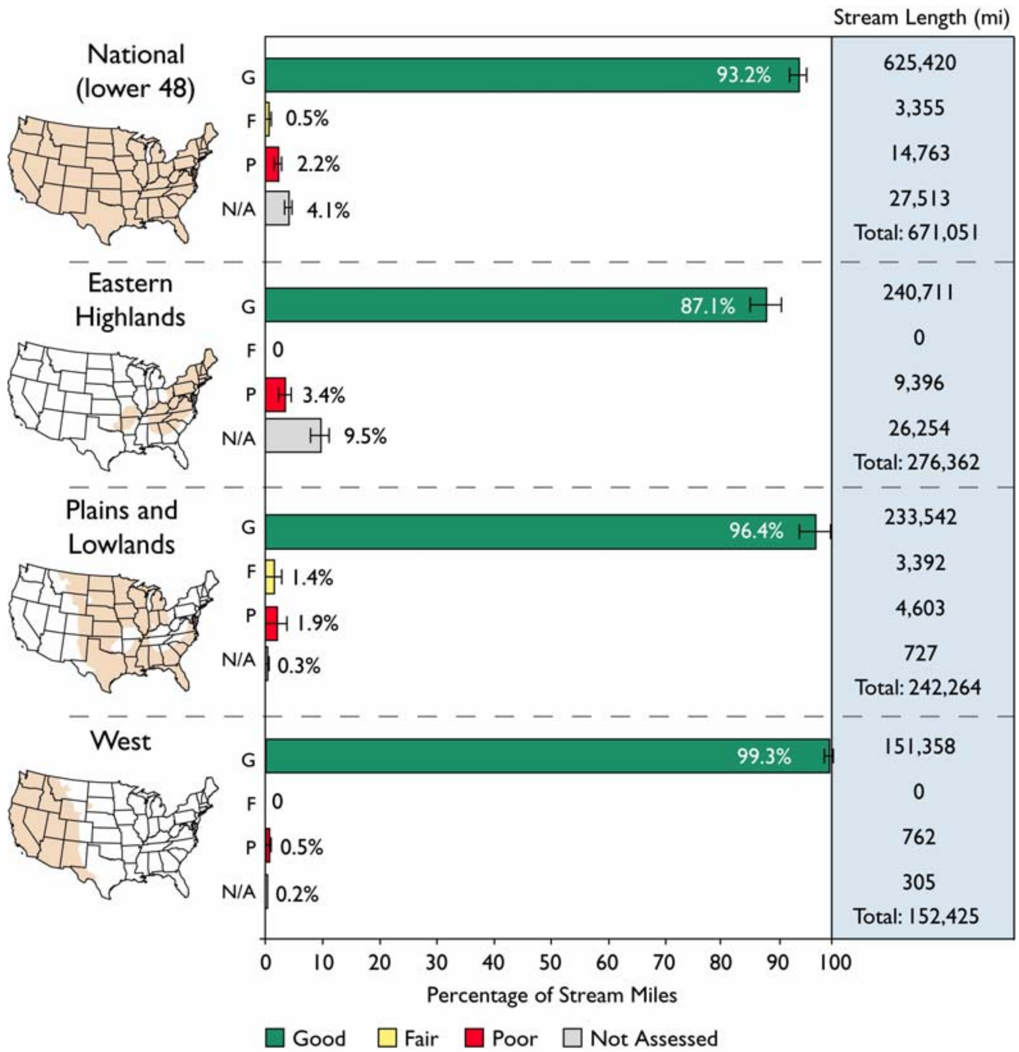

Figure 2-6. Acidification in U.S. streams.

Streams are acidic when acid-neutralizing capacity (ANC) values fall below zero. They are sensitive to acidification during rainfall events when ANC values are between 0 and 25 milliequilivents. Both ranges were scored as anthropogenically acidic in poor condition. Acidic streams with high levels of sulfate are associated with acid mine drainage. Low levels of sulfate indicate acid rain.

Physical Habitat Stressors

A number of human activities can potentially impact the physical habitat of streams upon which the biota rely. Soil erosion from road construction, poor agricultural practices, and other disturbances can result in increases in the amount of fine sediments on the stream bottom, which negatively impact macroinvertebrates and fish. Physical alterations to vegetation along the stream banks, alteration to the physical characteristics within the stream itself, and changes in the flow of water all have the potential to impact stream biota.

Although many aspects of stream and river habitats can become stressful to aquatic organisms when altered or modified, the WSA focuses on four specific aspects of habitat: streambed sediments, in-stream habitat complexity, riparian vegetation, and riparian disturbance.

Streambed Sediments

The supply of water and sediments from drainage areas affects the shape of river channels and the size of streambed particles in streams and rivers. One measure of the interplay between sediment supply and transport is relative bed stability (RBS). The measure of RBS used in the WSA is a ratio that compares the particle size of observed sediments to the size of sediments that each stream can move or scour during its flood stage (based on the size, slope, and other physical characteristics of the stream channel). The expected RBS ratio differs naturally among regions, depending upon landscape characteristics that include geology, topography, hydrology, natural vegetation, and natural disturbance history.

Values of the RBS ratio can be either substantially lower (e.g., finer, more unstable streambeds) or higher (e.g., coarser, more stable streambeds) than those expected, based on the range found in least-disturbed reference sites. Both high and low values are considered to be indicators of ecological stress. Excess fine sediments on the streambed can destabilize streams when the supply of sediments from the landscape exceeds the ability of the stream to move them downstream. This imbalance results from a number of human uses of the landscape, including agriculture, road building, construction, and grazing. The WSA focuses on increase in streambed sediment, represented by lower than expected streambed stability as the indicator of concern.

Lower than expected streambed stability may result either from high inputs of fine sediments (e.g., erosion) or increases in flood magnitude or frequency (e.g., hydrologic alteration). When low RBS results from fine sediment inputs, stressful ecological conditions can develop because fine sediments begin filling in the habitat spaces between stream cobbles and boulders. The instability (low RBS) resulting from hydrologic alteration can be a precursor to channel incision and gully formation.

Findings for Streambed Sediments

Approximately 25% of the nation's stream miles have streambed sediment characteristics in poor condition compared to regional reference conditions (Figure 2-7). Streambed sediment characteristics are rated fair in 20% of stream miles and rated good in 50% of stream miles compared to reference. The two regions with the highest percentage of streams in poor condition are the Eastern Highlands (28%) and the Plains and Lowlands (26%), while the West region has the lowest percentage (17%) of streams in poor condition. Streams with significantly more stable streambeds than reference (e.g., evidence of hardening and scouring, streams that have been lined with concrete) were not included in this indicator. These stream conditions occurred so rarely in the survey that it was not necessary to separate them from the overall population.

Streambed Sediments

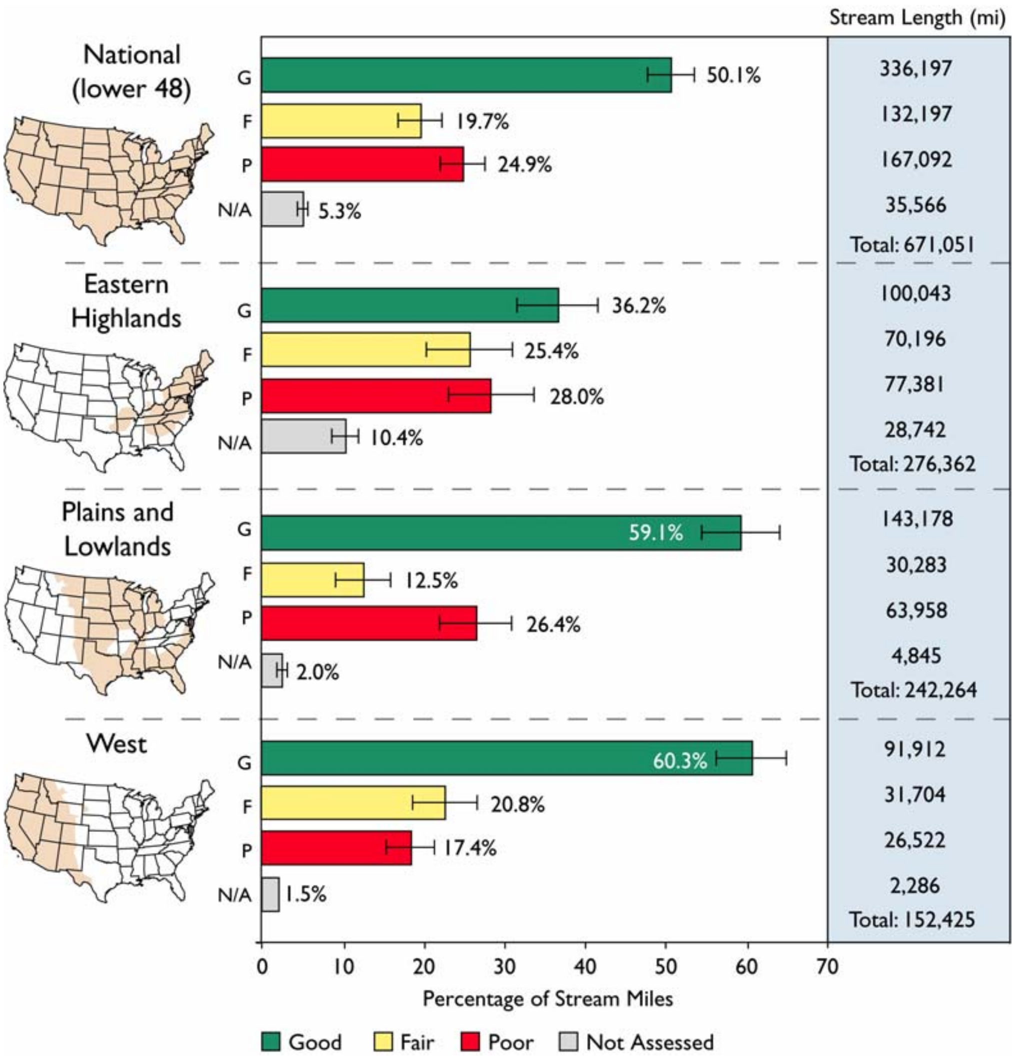

Figure 2-7. Streambed sediments in U.S. streams.

This indicator measures the percentage of stream beds impacted by increased sedimentation, which indicates alteration from reference conditions as defined by least-disturbed reference sites in each of the nine WSA ecoregions.

In-Stream Fish Habitat

The most diverse fish and macroinvertebrate assemblages are found in streams and rivers that have complex forms of habitat, such as large wood within the stream banks, boulders, undercut banks, and tree roots. Human use of streams and riparian areas often results in the simplification of this habitat, with potential effects on biological integrity. The WSA used a habitat complexity measure that sums the amount of in-stream fish concealment features and habitat consisting of undercut banks, boulders, large pieces of wood, brush, and cover from overhanging vegetation within a stream and its banks.

Findings for In-stream Fish Habitat

In-stream fish habitat is in poor condtion in 20% of stream miles across the United States. Twenty-five percent of stream miles are in fair condition, and 52% of stream miles are in good condition (Figure 2-8). The highest proportion in poor condition is in the Plains and Lowlands (37%); only 12% of stream miles in the West and 8% in the Eastern Highlands rated poor for in-stream fish habitat.

In-stream Fish Habitat

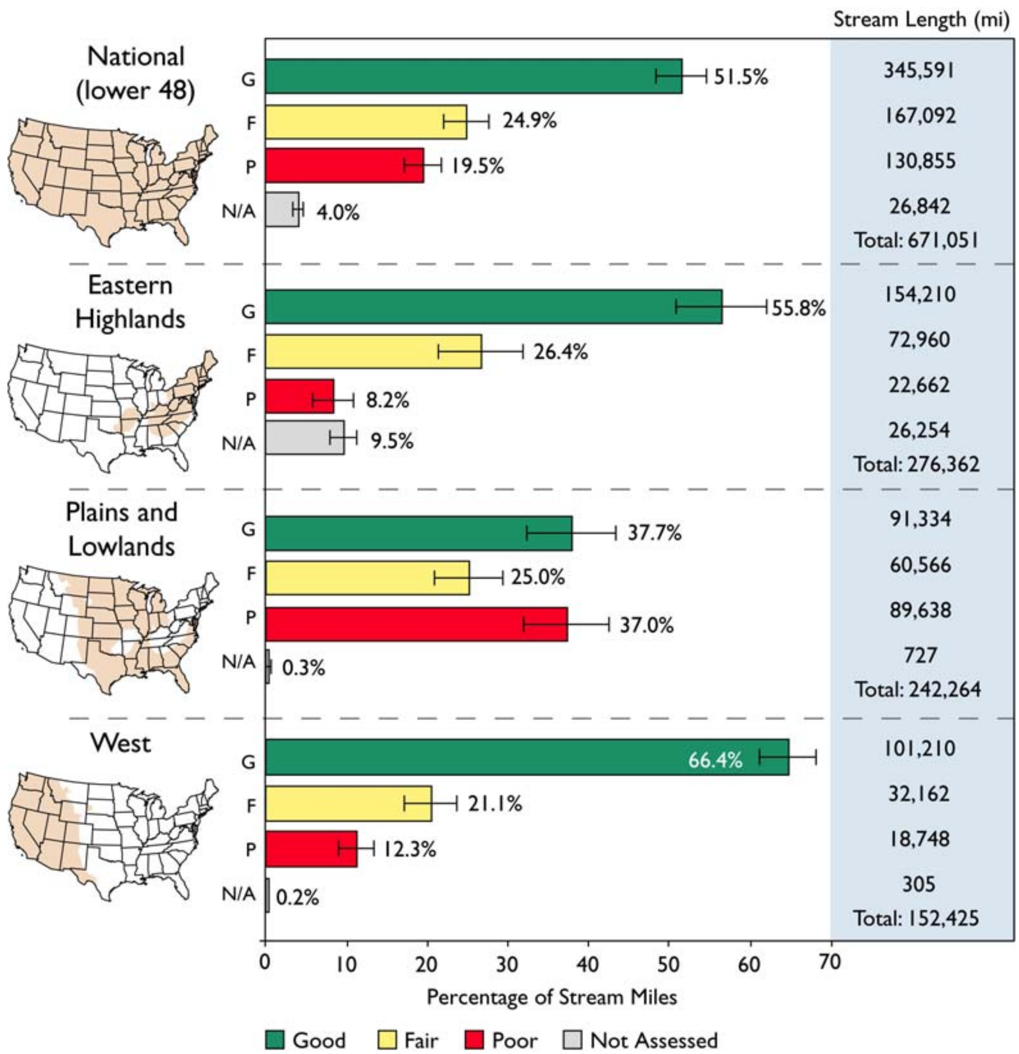

Figure 2-8. In-stream fish habitat in U.S. streams.

This indicator sums the amount of in-stream habitat that field crews found in the stream. Habitat consisted of undercut banks, boulders, large pieces of wood, and brush. Thresholds are based on conditions at regional reference sites.

Riparian Vegetative Cover

The presence of a complex, multi-layered vegetation corridor along streams and rivers is a measure of how well the stream network is buffered against sources of stress in the watershed. Intact riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent streambank erosion, provide shade to reduce water temperature, and provide leaf litter and large wood that serve as food and habitat for stream organisms. The presence of large, mature canopy trees in the riparian corridor indicates its longevity, whereas the presence of smaller woody vegetation typically indicates that riparian vegetation is reproducing and suggests the potential for future sustainability of the riparian corridor. The WSA uses a measure of riparian vegetative cover that sums the amount of woody cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees.

Findings for Riparian Vegetative Cover

Nineteen percent of stream length nationally is in poor condition due to severely simplified riparian vegetation (Figure 2-9). About 28% of stream miles are in fair condition and almost half (48%) are in good condition relative to least-disturbed reference sites in the 9 WSA ecoregions. The West (12%) and Eastern Highlands (18%) have similar proportions of stream length with riparian vegetation in poor condition, though this equates to greater numbers of stream miles in the east where water is more abundant. In the Plains and Lowlands region, a larger proportion of stream length (26%) has riparian vegetation in poor condition.

Riparian Vegetative Cover

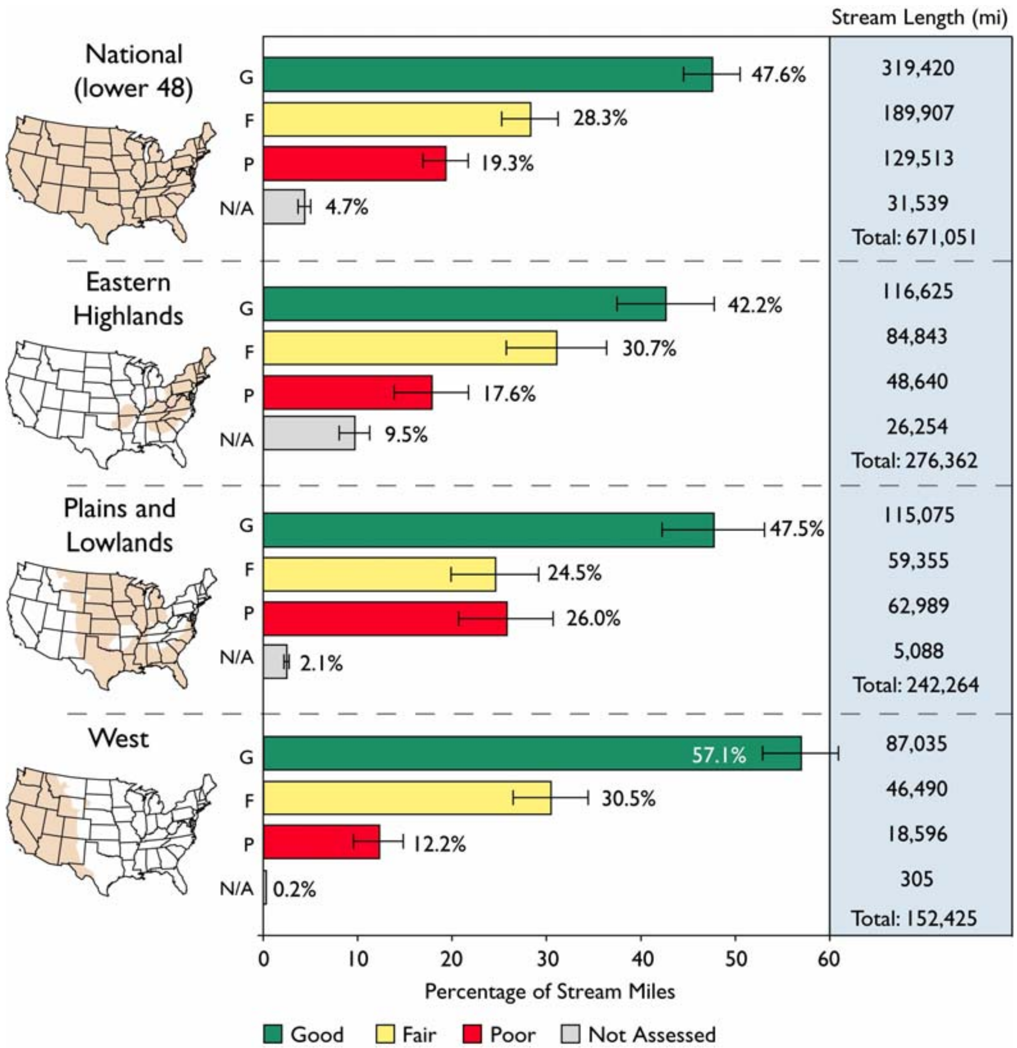

Figure 2-9. Riparian vegetative cover in U.S. streams.

This indicator sums the amount of woody cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees. Thresholds are based on conditions at regional reference sites.

Riparian Disturbance

The vulnerability of the stream network to potentially harmful human activities increases with the proximity of those activities to the streams. The WSA used a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and disturbances along the stream reach and weights them according to how close they are to the stream channel. The index generally varies from 0 (no observed disturbance) to 6 (four types of disturbance observed in the stream, throughout the reach; or six types observed on the banks, throughout the reach).

Findings for Riparian Disturbance

Nationally, 26% of stream length has high levels of human influence along the riparian zone that fringes stream banks, and 24% has relatively low levels of disturbance (Figure 2-10). The highest proportion of stream length with high riparian disturbance is in the Eastern Highlands region (29%), followed by the Plains and Lowlands (26%) and the West (19%). One of the striking findings of the WSA is the widespread distribution of intermediate levels of riparian disturbance: 47% of United States streams have intermediate levels of riparian disturbance when compared to reference sites, and similar percentages are found in each of the three climatic and landform regions.

It is worth noting that for the nation overall and the three broad regions, the length of stream with good riparian vegetative cover was significantly higher than the length of stream with low levels of human disturbance in the riparian zone. This finding warrants additional investigation, but suggests that land managers and property owners are protecting and maintaining healthy riparian vegetation buffers, even along streams where disturbance from roads, agriculture, and grazing is widespread.

Riparian Disturbance

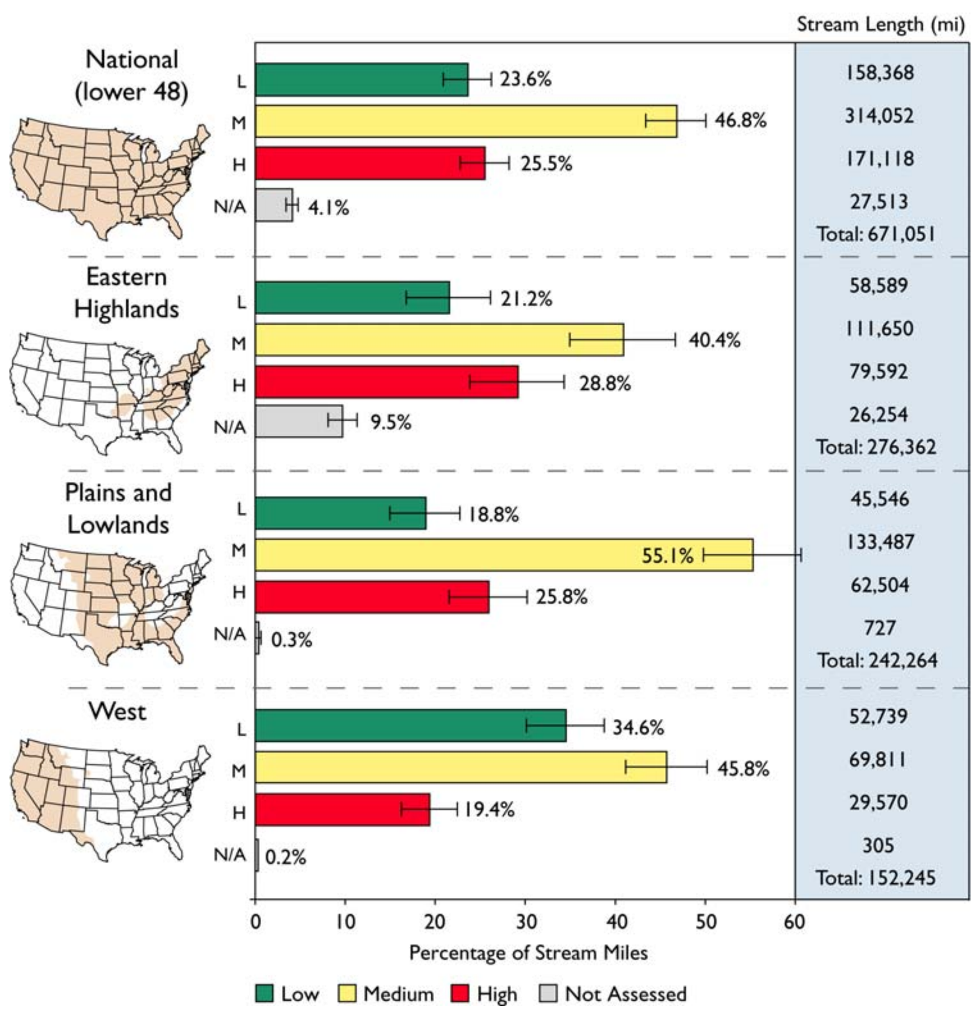

Figure 2-10. Riparian disturbance in U.S. streams.

This indicator is based on field observations of 11 different types of human influence (e.g., dams, pavement, pasture) and their proximity to a stream in 22 riparian plots along the stream. Streams scored medium if human influence was noted at half of the plots and high if it was observed at all of the plots.

Biological Stressors

Although most of the factors identified as stressors to streams and rivers are either chemical or physical, there are biological factors that also create stress in wadeable streams. Biological assemblages can be stressed by the presence of non-native species that can either prey on, or compete with, native species. In many cases, non-native species have been intentionally introduced to a waterbody; for example, brown trout and brook trout are common inhabitants of streams in the higher elevation areas of the western mountains and deserts, where they have been stocked as game fish.

When non-native species become established in either vertebrate or invertebrate assemblages, their presence conflicts with the definition of biological integrity that the CWA is designed to protect (i.e., "having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region"). Therefore, to the extent that non-native species compete with — and potentially exclude — native species, they might be considered a threat to biological integrity. These indicators were not included in this initial assessment of streams, but may be included in future assessments.

Ranking of Stressors

An important prerequisite to making policy and management decisions is to understand the relative magnitude or importance of potential stressors. It is important to consider both the prevalence of each stressor (i.e., what is its extent, in miles of stream, and how does it compare to other stressors?) and the severity of each stressor (i.e., how much influence does it have on biological condition, and is its influence greater or smaller than the influence of other stressors?) The WSA presents separate rankings of the relative extent and the relative severity of stressors to the nation's flowing waters. Ideally, both of these factors (extent and effect) should be combined into a single measure of relative importance. EPA is pursuing methodologies for combining the two rankings and will present them in future assessments.

Relative Extent

Figure 2-11 shows the WSA stressors, each ranked according to the proportion of stream length that is in poor condition. Results are presented for the nation (top panel) and for each climatic and landform region, with the stressors ordered (in all panels) according to their relative extent nationwide.

Figure 2-11 reveals that excess total nitrogen is the most pervasive stressor for the nation overall, although it is not the most pervasive in each region. Nationally, approximately 32% of the stream length shows high levels of nitrogen compared to reference conditions. In the Plains and Lowlands, nitrogen is at high levels in 27% of stream length, whereas this proportion climbs to 42% in the Eastern Highlands. Even in the West, where levels of disturbance are generally lower than the other climatic regions, excess total nitrogen is found in 21% of the stream length. Phosphorus exhibits comparable patterns to nitrogen and is the second most pervasive stressor nationally.

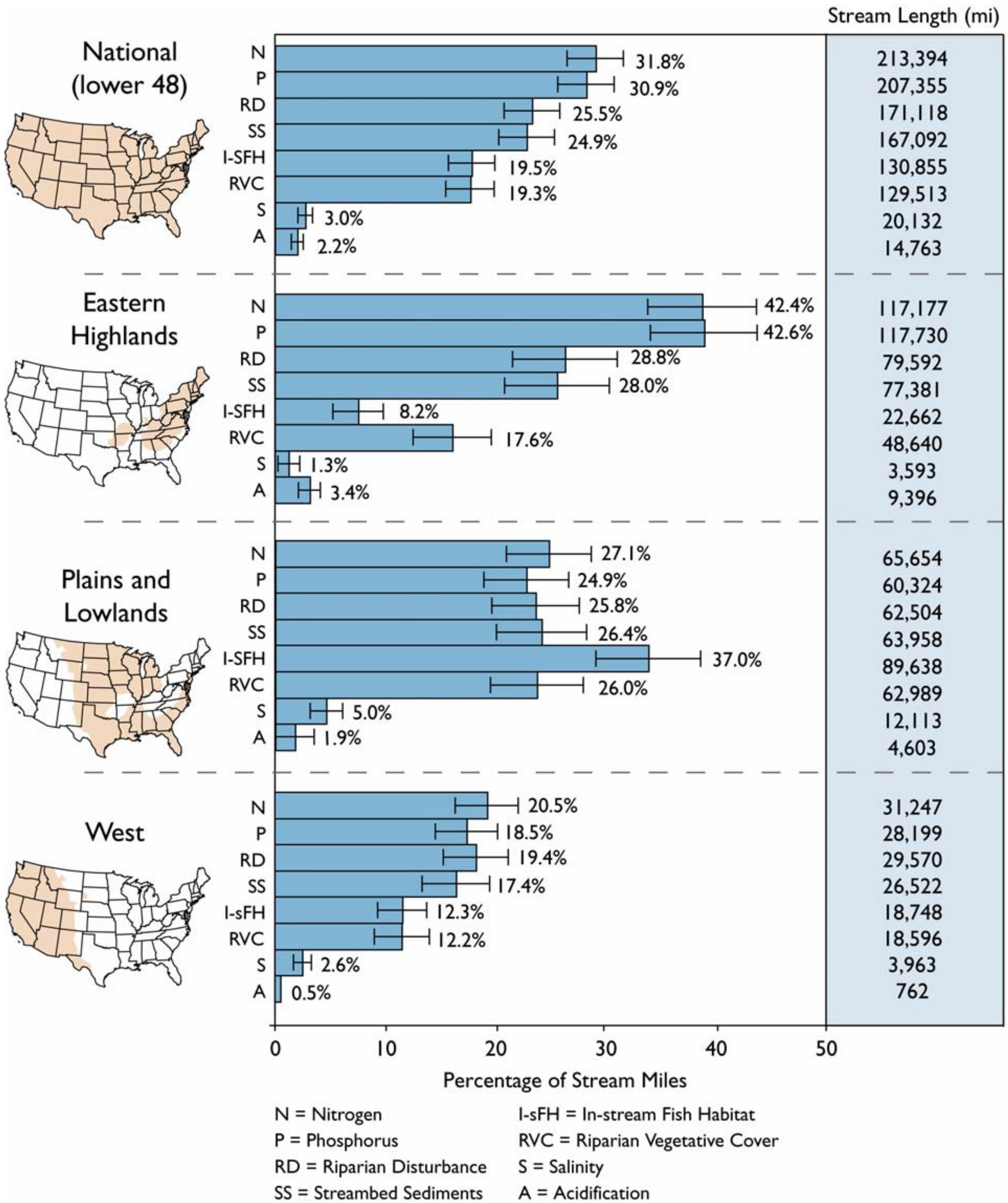

Figure 2-11. Relative extent of stressors (i.e., proportion of stream length ranked in poor category for each stressor).

The least common stressors nationally are salinity and acidification. Only 3% and 2%, respectively, of stream length across the lower 48 states have salinity and acidification levels in the most-disturbed category. Although these stressors are not present in large portions of the nation's streams, they can have a significant impact where they do occur.

The extent of stressors measured in the WSA varies across the three major regions. In the Plains and Lowlands, the stressor rated poor for the most stream miles is loss of in-stream fish habitat. In the Eastern Highlands, excess total nitrogen and excess total phosphorus levels are rated high in more than 42% of the stream length. In the West, all stressors are found in 21% or less of stream length, though nitrogen, phosphorus, and riparian disturbance are the most widespread stressors in this region as well.

Relative Risk of Stressors to Biological Condition

In order to address the question of severity of stressor effects, this report borrows the concept of relative risk from the medical field because of the familiarity of this language. We have all heard, for example, that we run a greater risk of developing heart disease if we have high cholesterol levels. Often such results are presented in terms of a relative-risk ratio—e.g., the risk of developing heart disease is four times higher for a person with total cholesterol level greater than 300 mg than for a person with total cholesterol of less than 150 mg.

The relative-risk values for stressors presented in Figure 2-12 can be interpreted in the same way as the cholesterol example. For each of the key stressors, this figure depicts how much more likely a stream is to have poor biological condition if a stressor is rated as poor or found in high concentrations than if the stressor is rated as good or found in low concentrations. Because different aspects of the macroinvertebrate assemblage (i.e., biological condition vs. taxa loss) are expected to be affected by different stressors, the WSA calculates relative risk separately for each of the biological condition indicators.

A relative-risk value of one indicates that there is no association between the stressor and the biological indicator, whereas values greater than one suggest the stressor poses greater relative risk to biological condition. The WSA also calculates confidence intervals (Figure 2-12) for each relative risk ratio. When the confidence intervals for any given ratio do not include the value of one, the relative risk estimate is statistically significant.

The significant relative risks shown in Figure 2-12 give us an idea of the severity of each stressor's effect on the macroinvertebrate community in streams. Almost all of the stressors evaluated for WSA were associated with increased risk for macroinvertebrates. Evaluating relative risk provides insights as to which stressors we might focus on to improve biological condition. Excess nitrogen, phosphorus, and streambed sediments stand out as having the most significant impacts on biological condition based on both the Macroinvertebrate Index and taxa loss indicators. Findings show that relatively high levels of nutrients or excess streambed sediments increases the risk of finding poor macroinvertebrate condition by 2 to 4 times.

There are differences in relative risk from a geographic perspective. In general, the West region exhibits a higher relative risk for the majority of stressors than seen in the Eastern Highlands and the Plains and Lowlands regions. There are also differences associated with the different indicators of biological condition. The O/E taxa loss indicator has somewhat higher relative risk ratios for most of the stressors than the Macroinvertebrate Index. Additional analysis is needed to further explore these differences.

In this assessment of relative risk, it is impossible to separate completely the effects of individual stressors that often occur together. For example, streams with high nitrogen concentrations often also exhibit high phosphorus levels, and streams with high riparian disturbance often have sediments far in excess of expectations. The analysis presented in Figure 2-12 treats the stressors as if they operate independently, even though we know they do not.

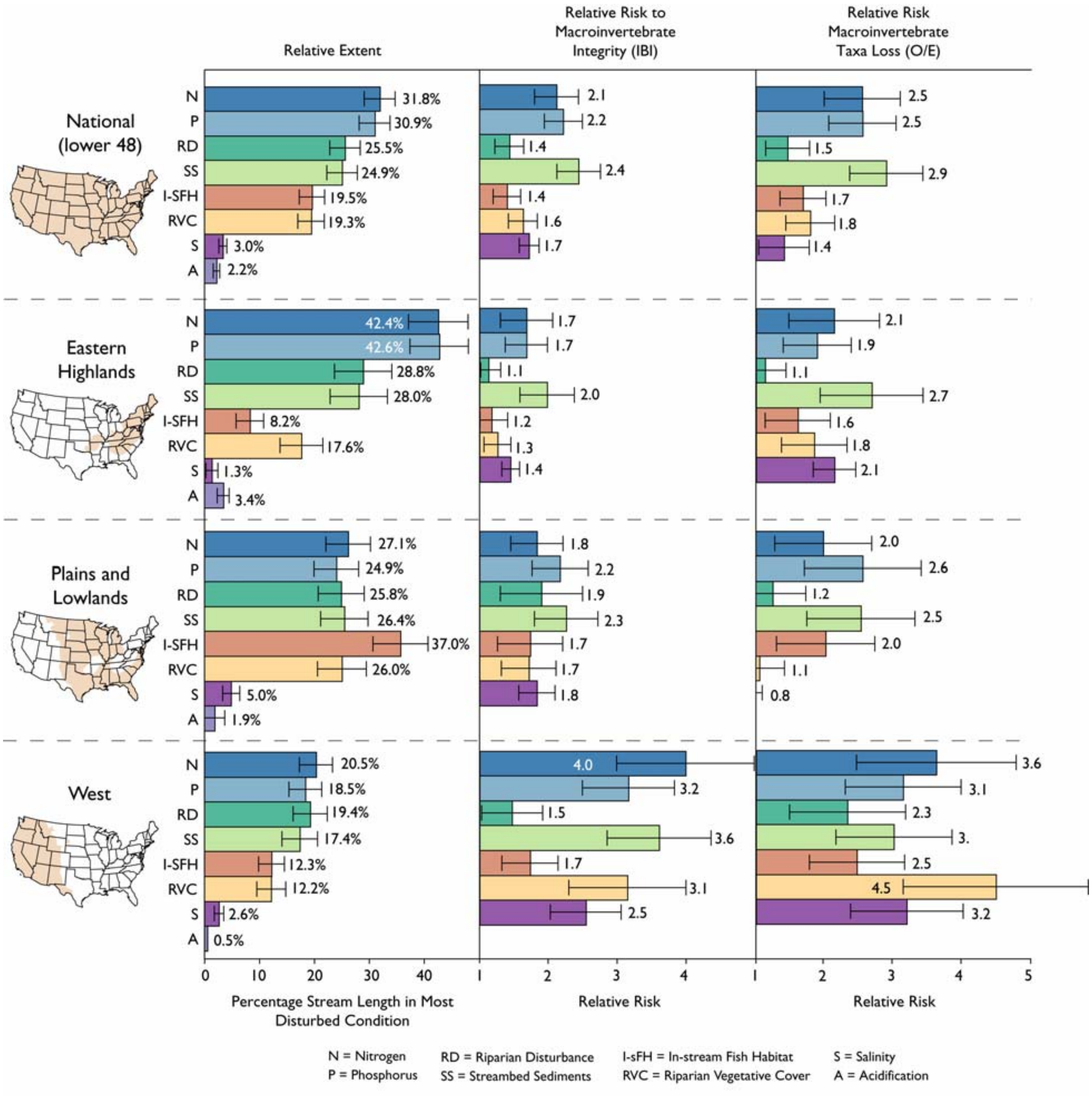

Figure 2-12. Relative extent of stressors and relative risk for Macroinvertebrate Index of Biotic Condition and macroinvertebrate taxa loss.

This calculation measures the association between a stressor and biological condition and answers the question "what is the increased likelihood of poor biological condition when stressor X is rated in poor condition?" It is important to note that this calculation treats each stressor independently and does not account for the effects of combinations of stressors.

Combining Extent and Relative Risk

The most comprehensive assessment of the ranking of stressors comes from combining the relative extent (Figure 2-11) and relative risk (Figure 2-12) results. Stressors that pose the greatest overall risk to biological integrity will be those that are both widespread (i.e., rank high in terms of extent in Figure 2-11) and whose effects are potentially severe (i.e., exhibit high relative risk ratios in Figure 2-12). The WSA facilitates this combined evaluation of stressor importance by including side-by-side comparisons of relative extent and relative risk in Figure 2-12.

A quick examination of nationwide results suggests some common patterns for key stressors and the two indicators of biological condition. Total nitrogen, total phosphorus, and excess streambed sediments are stressors posing the greatest relative risk nationally (relative risk greater than 2) and they also occur in 25 – 32% of the stream length nationally. This suggests that management decisions aimed at reducing excess sedimentation and nitrogen and phosphorus loadings to streams could have a positive impact on macroinvertebrate biological integrity and prevent further taxa loss across the country.

High salinity in the West region is strongly associated with poor biological integrity (relative risk = 2.5) and macroinvertebrate taxa loss (relative risk > 3.1 or = 3.2). However, its rarity (salinity affects only 3% of stream length in the West) suggests that excess salinity is a local issue requiring a locally targeted management approach rather than a national or regional effort.

Relative risks for all stressors in the West are consistently larger than for the nation overall or for the other two regions, yet the relative extent of these stressors is consistently lower in the West. This suggests that although the stressors are not widespread in the West, western streams are particularly sensitive to a variety of disturbances. Although this subject needs more investigation, this might be interpreted to mean that the apparently low relative risks in the Eastern Highlands and in the Plains and Lowlands reflect streams that may be less sensitive to stressors because of their longer history of disturbance.